A Guiding Light at the Nanoscale: Wire and Ribbon Photonics

LBNL researchers, under the direction of Peidong Yang, extending their earlier work with semiconductor "nanoribbon" waveguides, have shown that these materials can serve to route laser pulses through a variety of complex structures and, in fact, though a liquid. This research with single crystals of tin oxide up to 1.5 mm in length, and a few hundred nanometers in width and thickness is an important step towards realizing the promise of extremely high speed photonic technology.

In photonic technology, information is transferred via light rather than electrons. It presents several intrinsic advantages. For example, whereas electrons must carry information sequentially, one electron at a time, in photonics there is no limit to the number of information packets that can be transmitted simultaneously. Hints of the potential of photonics can be glimpsed in today's fiber-optic communications, in which a single optical fiber can carry the equivalent of 300,000 telephone calls at the same time. In fact, the power of fully realized photonics goes far beyond this. For example, it has been estimated that a photonic internet could transmit data at 160 gigabits per second, thousands of times faster than today's typical "high-speed" connection. Another possible application is the optical computer, which could solve problems in seconds that would take today's electronic computers months or even years.

NANORIBBONS AS FLEXIBLE OPTICAL WAVE GUIDES FOR LASERS: MULTI-CHANNEL FILTERS, 90° TURNS, IN LIQUID

For the promise of photonics to be delivered, however, scientists must first find a way to manipulate and route photons with the same dexterity now available for manipulating and routing electrons. Complicating the problem is the fact that electrons tend to stay in the wires used to route them, but photons require specially designed "waveguides" to keep them on course. Developing these on the scale of modern IC circuitry has been challenging.

The LBNL team had previously shown (MSD Research Highlight 04-7, [10/04]) that chemically synthesized tin oxide (SnO_2) nanoribbons can be used as flexible optical waveguides. In this new work with collaborators at NASA Ames, they showed that it is possible to transport light pulses from their GaN or ZnO nanowire lasers to the ribbon waveguides, a prerequisite if photonic devices are to be useful in communications or computing applications. Next, they demonstrated that networks of tin oxide nanoribbons of controlled size can be used as multi-channel filters for separating the component colors of white light and routing them through individual channels. They also made an optical crossbar grid of two pairs of orthogonal ribbons that conducts light through abrupt 90˚ angles, analogous to the cross-bars in nanowire electronics. Such crossbar structures could form the basis of optical nanowire logic. Finally, they showed that nanowires and nanoribbons can be used to guide light in water and other liquids. In one test, the tip of a nanoribbon was embedded in a droplet of dye, and a pulse of blue light was then sent into the far end of the ribbon. This produced a strong fluorescence within the droplet, a fraction of which was captured by the ribbon cavity and guided back to the ribbon's far end, proving that these waveguides are capable of routing signals both to and from liquids.

Integrated nanowire laser and nanoribbon waveguide assemblies are the newest addition to the growing photonics "toolbox" which also includes nanoscale photodetectors. The experiments with liquids suggest a role for nanowire light delivery in integrated on-chip chemical analysis and biological spectroscopy.

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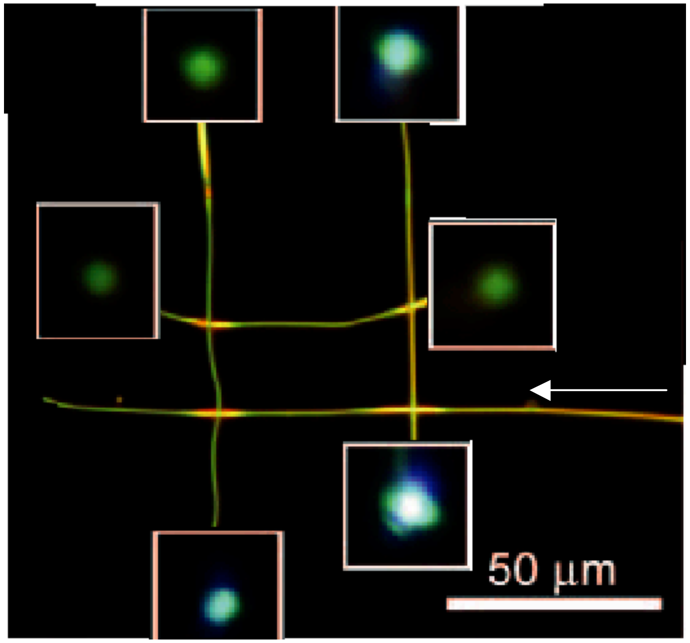
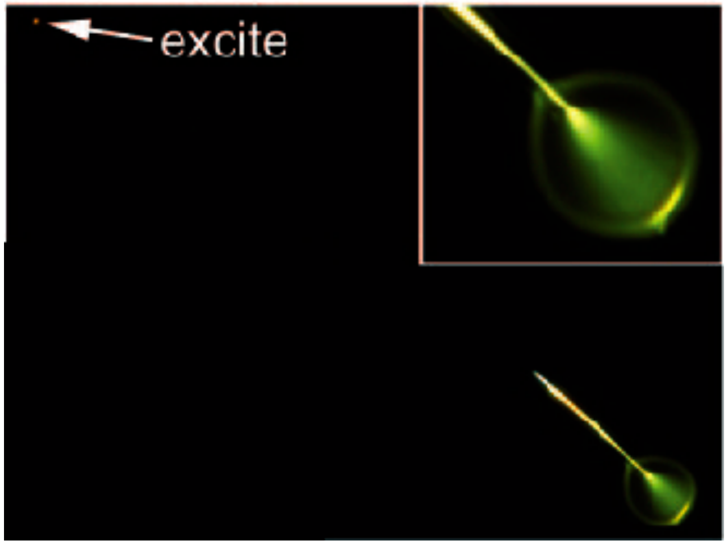
A Guiding Light on the Nanoscale: Wire and Ribbon Photonics

Multichannel optical filtering. *A single SnO_2 source ribbon of ~250 nm diameter transmitting white light is coupled to three output ribbons (1,2,3) with diameters of ~200, 150 and 100 nm, which carry green, aqua, and sepia light respectively. The source ribbon transmits the white light through to the end.*

GaN Nanowire at top is coupled at arrow to a SnO_2 nanoribbon waveguide. *Optical excitation of the nanowire produces laser pulses which propagate though the SnO_2 nanoribbon and can be detected at its uncoupled end.*



Optical routing: *White light sent (arrow) into a network of SnO_2 nanoribbons (yellow lines), is emitted (green and blue dots in the boxes) at the ends of the ribbons. Size and junction optical coupling result in different emission colors.*



Guiding in liquid. *A nanoribbon (not visible except at lower right) crosses the frame from upper left to lower right, where it is coupled to a water droplet containing a fluorescent dye. Excitation light from the ribbon produces green fluorescence in the droplet (detailed in inset), which propagates back up the ribbon where it can also be detected.*

Peidong Yang, 06-03